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THE TFTP PROTOCOL (REVISION 2)

Summary

TFTP is a very simple protocol used to transfer files. It is from this that its name comes, Trivial File Transfer Protocol or TFTP. Each nonterminal packet is acknowledged separately. This document describes the protocol and its types of packets. The document also explains the reasons behind some of the design decisions.

ACKNOWLEDGEMENTS

The protocol was originally designed by Noel Chiappa, and was redesigned by him, Bob Baldwin and Dave Clark, with comments from Steve Szymanski. The current revision of the document includes modifications stemming from discussions with and suggestions from Larry Allen, Noel Chiappa, Dave Clark, Geoff Cooper, Mike Greenwald, Liza Martin, David Reed, Craig Milo Rogers (of UCS-ISI), Kathy Yellick, and the author. The acknowledgement and retransmission scheme was inspired by TCP, and the error mechanism was suggested by PARC's EFTP abort message.

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1. Purpose

TFTP is a simple protocol to transfer files, and therefore was named the Trivial File Transfer Protocol or TFTP. It has been implemented on top of the Internet User Datagram protocol (UDP or Datagram) [2] so it may be used to move files between machines on different networks implementing UDP. (This should not exlude the possibility of implementing TFTP on top of other datagram protocols.) It is designed to be small and easy to implement. Therefore, it lacks most of the features of a regular FTP. The only thing it can do is read and write files (or mail) from/to a remote server. It cannot list directories, and currently has no provisions for user authentication. In common with other Internet protocols, it passes 8 bit bytes of data.

Three modes of transfer are currently supported: netascii [1] ; octet [2], raw 8 bit bytes; mail, netascii characters sent to a user rather than a file. Additional modes can be defined by pairs of cooperating hosts.

←←←←←←←←←←←←←←

[1] This is ascii as defined in "USA Standard Code for Information Interchange" [1] with the modifications specified in "Telnet Protocol Specification" [3]. Note that it is 8 bit ascii. The term "netascii" will be used throughout this document to mean this particular version of ascii.

[2] This replaces the "binary" mode of previous versions of this document.

2. Overview of the Protocol

Any transfer begins with a request to read or write a file, which also serves to request a connection. If the server grants the request, the connection is opened and the file is sent in fixed length blocks of 512 bytes. Each data packet contains one block of data, and must be acknowledged by an acknowledgment packet before the next packet can be sent. A data packet of less than 512 bytes signals termination of a transfer. If a packet gets lost in the network, the intended recipient will timeout and may retransmit his last packet (which may be data or an acknowledgment), thus causing the sender of the lost packet to retransmit that lost packet. The sender has to keep just one packet on hand for retransmission, since the lock step acknowledgment guarantees that all older packets have been received. Notice that both machines involved in a transfer are considered senders and receivers. One sends data and receives acknowledgments, the other sends acknowledgments and receives data.

Most errors cause termination of the connection. An error is signalled by sending an error packet. This packet is not acknowledged, and not retransmitted (i.e., a TFTP server or user may terminate after sending an error message), so the other end of the connection may not get it. Therefore timeouts are used to detect such a termination when the error packet has been lost. Errors are caused by three types of events: not being able to satisfy the request (e.g., file not found, access violation, or no such user), receiving a packet which cannot be explained by a delay or duplication in the network (e.g. an incorrectly

formed packet), and losing access to a necessary resource (e.g., disk full or access denied during a transfer).

TFTP recognizes only one error condition that does not cause termination, the source port of a received packet being incorrect. In this case, an error packet is sent to the originating host.

This protocol is very restrictive, in order to simplify implementation. For example, the fixed length blocks make allocation straight forward, and the lock step acknowledgement provides flow control and eliminates the need to reorder incoming data packets.

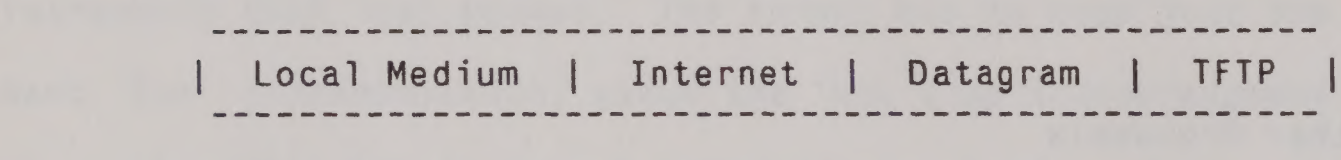
3. Relation to other Protocols

As mentioned TFTP is designed to be implemented on top of the Datagram protocol. Since Datagram is implemented on the Internet protocol, packets will have an Internet header, a Datagram header, and a TFTP header. Additionally, the packets may have a header (LNI, ARPA header, etc.) to allow them through the local transport medium. As shown in Figure 3-1, the order of the contents of a packet will be: local medium header, if used, Internet header, Datagram header, TFTP header, followed by the remainder of the TFTP packet. (This may or may not be data depending on the type of packet as specified in the TFTP header.) TFTP does not specify any of the values in the Internet header. On the other hand, the source and destination port fields of the Datagram header (its format is given in the appendix) are used by TFTP and the length field reflects the size of the TFTP packet. The transfer identifiers (TID's)

used by TFTP are passed to the Datagram layer to be used as ports; therefore they must be between 0 and 65,535. The initialization of TID's is discussed in the section on initial connection protocol.

The TFTP header consists of a 2 byte opcode field which indicates the packet's type (e.g., DATA, ERROR, etc.) These opcodes and the formats of the various types of packets are discussed further in the section on TFTP packets.

Figure 3-1: Order of Headers



4. Initial Connection Protocol

A transfer is established by sending a request (WRQ to write onto a foreign file system, or RRQ to read from it), and receiving a positive reply, an acknowledgment packet for write, or the first data packet for read. In general an acknowledgment packet will contain the block number of the data packet being acknowledged. Each data packet has associated with it a block number; block numbers are consecutive and begin with one. Since the positive response to a write request is an acknowledgment packet, in this special case the block number will be zero. (Normally, since an acknowledgment packet is acknowledging a data packet, the acknowledgment packet will contain the block number of the data packet being acknowledged.) If the reply is an error packet, then

the request has been denied.

In order to create a connection, each end of the connection chooses a TID for itself, to be used for the duration of that connection. The TID's chosen for a connection should be randomly chosen, so that the probability that the same number is chosen twice in immediate succession is very low. Every packet has associated with it the two TID's of the ends of the connection, the source TID and the destination TID. These TID's are handed to the supporting UDP (or other datagram protocol) as the source and destination ports. A requesting host chooses its source TID as described above, and sends its initial request to the known TID 69 decimal (105 octal) on the serving host. The response to the request, under normal operation, uses a TID chosen by the server as its source TID and the TID chosen for the previous message by the requestor as its destination TID. The two chosen TID's are then used for the remainder of the transfer.

As an example, the following shows the steps used to establish a connection to write a file. Note that WRQ, ACK, and DATA are the names of the write request, acknowledgment, and data types of packets respectively. The appendix contains a similar example for reading a file.

1. Host A sends a "WRQ" to host B with source= A's TID, destination= 69.

2. Host B sends a "ACK" (with block number= 0) to host A with source= B's TID, destination= A's TID.

At this point the connection has been established and the first data packet can be sent by Host A with a sequence number of 1. In the next step, and in all succeeding steps, the hosts should make sure that the source TID matches the value that was agreed on in steps 1 and 2. If a source TID does not match, the packet should be discarded as erroneously sent from somewhere else. An error packet should be sent to the source of the incorrect packet, while not disturbing the transfer.
This can be done only if the TFTP in fact receives a packet with an incorrect TID. If the supporting protocols do not allow it, this particular error condition will not arise.

The following example demonstrates a correct operation of the protocol in which the above situation can occur. Host A sends a request to host B. Somewhere in the network, the request packet is duplicated, and as a result two acknowledgments are returned to host A, with different TID's chosen on host B in response to the two requests. When the first response arrives, host A continues the connection. When the second response to the request arrives, it should be rejected, but there is no reason to terminate the first connection. Therefore, if different TID's are chosen for the two connections on host B and host A checks the source TID's of the messages it receives, the first connection can be maintained while the second is rejected by returning an error packet.

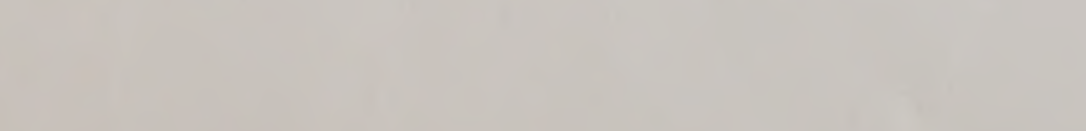
5. TFTP Packets

TFTP supports five types of packets, all of which have been mentioned above:

opcode	operation
1	Read request (RRQ)
2	Write request (WRQ)
3	Data (DATA)
4	Acknowledgment (ACK)
5	Error (ERROR)

The TFTP header of a packet contains the opcode associated with that packet.

Figure 5-1: RRQ/WRQ packet



RRQ and WRQ packets (opcodes 1 and 2 respectively) have the format shown in Figure 5-1. The file name is a sequence of bytes in netascii terminated by a zero byte. The mode field contains the string "netascii", "octet", or "mail" (or any comibnation of upper and lower case, such as "NETASCII", NetAscii", etc.) in netascii indicating the three modes defined in the protocol. A host which receives netascii mode data must translate the data to its own format. Octet mode is used to transfer a file that is in the 8-bit format of the machine from which the file is being transferred. It is assumed that each type of machine has a single 8-bit format that is more common, and that that format is

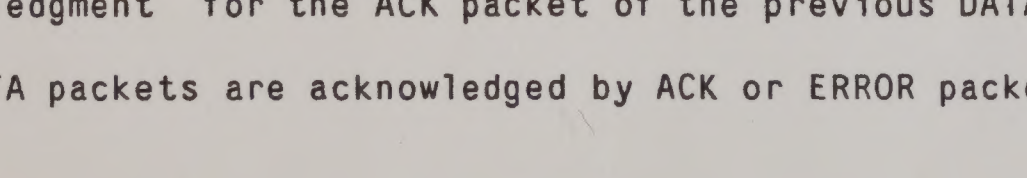
chosen. For example, on a DEC-20, a 36 bit machine, this is four 8-bit bytes to a word with four bits of breakage. If a host receives a octet file and then returns it, the returned file must be identical to the original. Mail mode uses the name of a mail recipient in place of a file and must begin with a WRQ. Otherwise it is identical to netascii mode. The mail recipient string should be of the form "username" or "username@hostname". If the second form is used, it allows the option of mail forwarding by a relay computer.

The discussion above assumes that both the sender and recipient are operating in the same mode, but there is no reason that this has to be the case. For example, one might build a storage server. There is no reason that such a machine needs to translate netascii into its own form of text. Rather, the sender might send files in netascii, but the storage server might simply store them without translation in 8-bit format. Another such situation is a problem that currently exists on DEC-20 systems. Neither netascii nor octet accesses all the bits in a word. One might create a special mode for such a machine which read all the bits in a word, but in which the receiver stored the information in 8-bit format. When such a file is retrieved from the storage site, it must be restored to its original form to be useful, so the reverse mode must also be implemented. The user site will have to remember some information to achieve this. In both of these examples, the request packets would specify octet mode to the foreign host, but the local host would be in some other mode. No such machine or application specific modes have been specified in TFTP, but one would be compatible with this

specification.

It is also possible to define other modes for cooperating pairs of hosts, although this must be done with care. There is no requirement that any other hosts implement these. There is no central authority that will define these modes or assign them names.

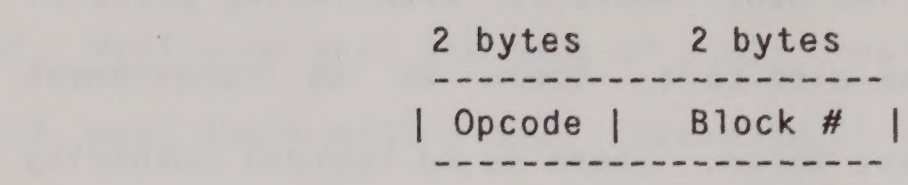
Figure 5-2: DATA packet



Data is actually transferred in DATA packets depicted in Figure 5-2. DATA packets (opcode = 3) have a block number and data field. The block numbers on data packets begin with one and increase by one for each new block of data. This restriction allows the program to use a single number to discriminate between new packets and duplicates. The data field is from zero to 512 bytes long. If it is 512 bytes long, the block is not the last block of data; if it is from zero to 511 bytes long, it signals the end of the transfer. (See the section on Normal Termination for details.)

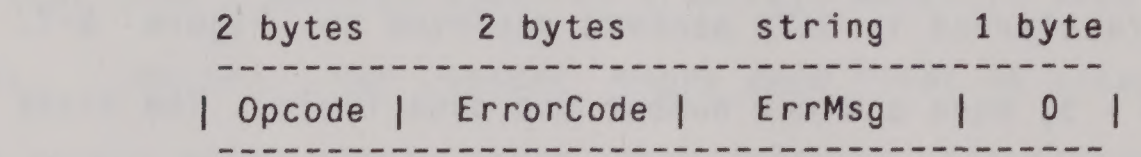
All packets other than those used for termination are acknowledged individually unless a timeout occurs. Sending a DATA packet is an acknowledgment for the ACK packet of the previous DATA packet. The WRQ and DATA packets are acknowledged by ACK or ERROR packets, while RRQ and

Figure 5-3: ACK packet



ACK packets are acknowledged by DATA or ERROR packets. Figure 5-3 depicts an ACK packet; the opcode is 4. The block number in an ACK echoes the block number of the DATA packet being acknowledged. A WRQ is acknowledged with an ACK packet having a block number of zero.

Figure 5-4: ERROR packet



An ERROR packet (opcode 5) takes the form depicted in Figure 5-4. An ERROR packet can be the acknowledgment of any other type of packet. The error code is an integer indicating the nature of the error. A table of values and meanings is given in the appendix. (Note that several error codes have been added to this version of this document.) The error message is intended for human consumption, and should be in netascii. Like all other strings, it is terminated with a zero byte.

6. Normal Termination

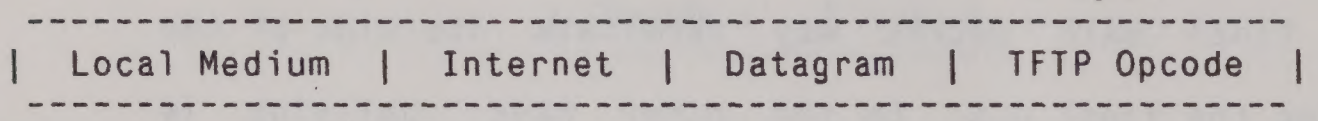
The end of a transfer is marked by a DATA packet that contains between 0 and 511 bytes of data (i.e. Datagram length < 516). This packet is acknowledged by an ACK packet like all other DATA packets. The host acknowledging the final DATA packet may terminate its side of the connection on sending the final ACK. On the other hand, dallying is encouraged. This means that the host sending the final ACK will wait for a while before terminating in order to retransmit the final ACK if it has been lost. The acknowledger will know that the ACK has been lost if it receives the final DATA packet again. The host sending the last DATA must retransmit it until the packet is acknowledged or the sending host times out. If the response is an ACK, the transmission was completed successfully. If the sender of the data times out and is not prepared to retransmit any more, the transfer may still have been completed successfully, after which the acknowledger or network may have experienced a problem. It is also possible in this case that the transfer was unsuccessful. In any case, the connection has been closed.

7. Premature Termination

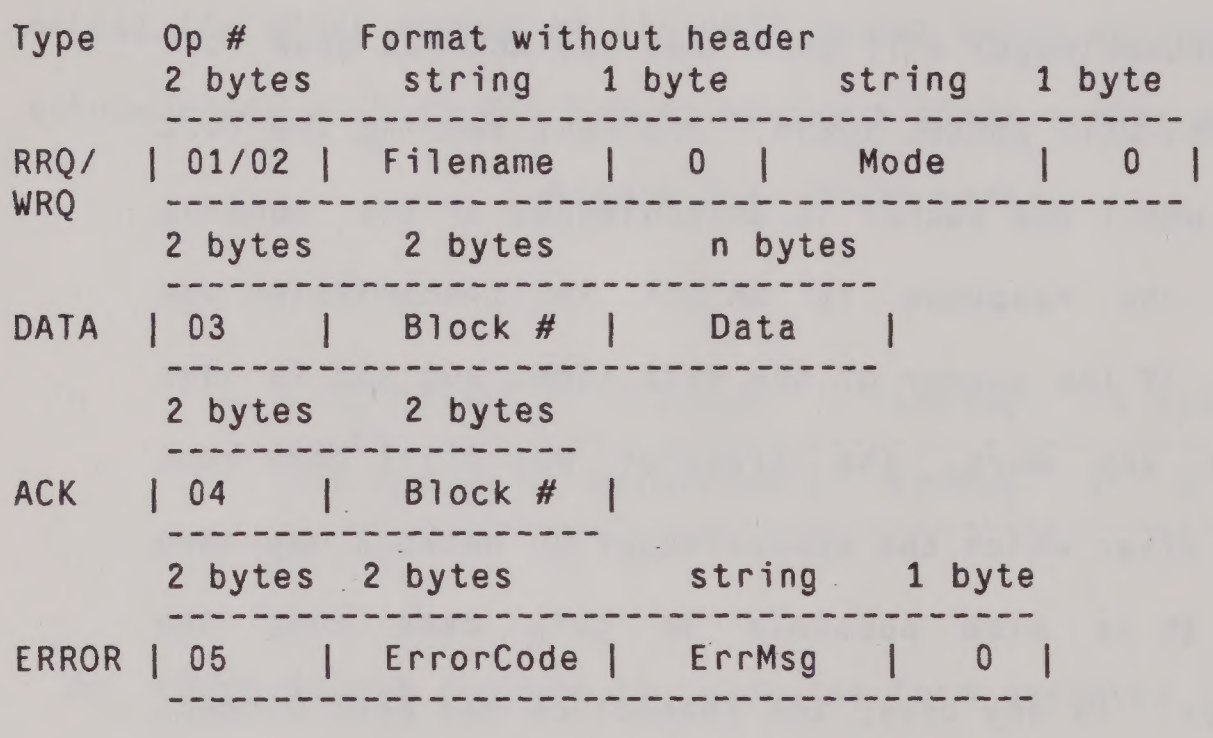
If a request can not be granted, or some error occurs during the transfer, then an ERROR packet (opcode 5) is sent. This is only a courtesy since it will not be retransmitted or acknowledged, so it may never be received. Timeouts must also be used to detect errors.

I. Appendix

Order of Headers



TFTP Formats



Initial Connection Protocol for reading a file

1. Host A sends a "RRQ" to host B with source= A's TID, destination= 69.

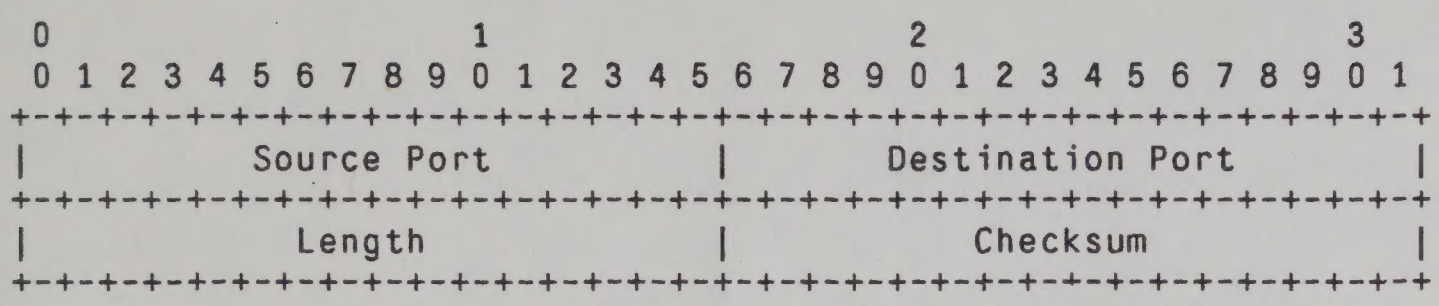
2. Host B sends a "DATA" (with block number= 1) to host A with source= B's TID, destination= A's TID.

Error Codes

Value	Meaning
0	Not defined, see error message (if any).
1	File not found.
2	Access violation.
3	Disk full or allocation exceeded.
4	Illegal TFTP operation.
5	Unknown transfer ID.
6	File already exists.
7	No such user.

Internet User Datagram Header [2][3]

Format



Values of Fields

Source Port — Picked by originator of packet.

Dest. Port — Picked by destination machine (69 for RRQ or WRQ).

Length — Number of bytes in packet after Datagram header.

Checksum — Reference 2 describes rules for computing checksum.[4] Field contains zero if unused.

Note: TFTP passes transfer identifiers (TID's) to the Internet User Datagram protocol to be used as the source and destination ports.

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3 This has been included only for convenience. TFTP need not be implemented on top of the Internet User Datagram Protocol.

4 The implementor of this should be sure that the correct algorithm is used here.

References

[1] USA Standard Code for Information Interchange, USASI X3.4-1968.

[2] Postel, Jon., "User Datagram Protocol," RFC768, August 28, 1980.

[3] "Telnet Protocol Specification," RFC764, June, 1980.